Specification

Light control film and backlight unit using the same

[Technical Field]

[0001]

The present invention relates to a light control film used for backlight units such as those for liquid crystal displays and so forth, and a backlight unit using the same.

[Background Art]

[0002]

For liquid crystal displays and so forth, backlight units of the edge light type or direct type are conventionally used. Since backlight units of the edge light type themselves can be manufactured with a small thickness, they are used for notebook computers etc., whereas backlight units of the direct type are used for large-sized liquid crystal television etc. in many cases.

[0003]

Lights emitted from these conventional backlight units contain components emitted along directions significantly inclined from the front direction. Lights emitted from backlight units of the edge light type, in particular, contain a lot of components emitted along directions significantly inclined from the front direction, and thus it is difficult to obtain high front luminance.

[0004]

Therefore, in the conventional backlight units, two or more optical films such as prism sheets and light diffusing films are used in combination in order to improve front luminance so that directions of lights should be directed to the front direction (see, for example, Japanese Patent Unexamined Publication (KOKAI) No. 9-127314 (claim 1,

paragraph 0034)).

[0005]

Although prism sheets can increase the ratio of lights emitted along the front direction (direction perpendicular to film surface) by surface design based on geometric optics. However, they have drawbacks that they are likely to suffer from an interference pattern due to regularly arranged convex portions, and that they cause glare if they are used alone and thus they impair visibility of images. Moreover, they unduly concentrate lights along the front direction, and therefore they cannot provide a wide viewing angle.

[0006]

On the other hand, if diffusion films are used alone, the front luminance becomes insufficient, although the aforementioned problems are not caused.

[0007]

Therefore, a prism sheet and a light diffusing film are used in combination as described above. However, the front luminance enhanced by the prism sheet is reduced by the use of the light diffusing film. Moreover, the films place in layers may generate Newton rings between the members, or scratches and so forth generated due to the contact of the members may cause a problem.

[Patent document 1] Japanese Patent Unexamined Publication (KOKAI) No. 9-127314

[Disclosure of the Invention]

[Problems to be solved by the Invention]

[0008]

Therefore, an object of the present invention is to provide a light control film that can surely improve front luminance when it is used alone or in combination with a prism sheet, has an appropriate light diffusing property,

and does not suffer from the problems of interference pattern and glare, and a backlight unit using the same.

[Means for solving the Problems]

[0009]

In order to achieve the aforementioned object, the inventor of the present invention conducted various researches on various factors defining surface profile of light control film such as convexo-concave profile, lengths, slopes with respect to film surface (base plane), heights and pitches of the convexo-concave portions, and as a result, they found that the front luminance could be improved by appropriately controlling slopes of the rough surface with respect to the film plane and the profile thereof and thereby efficiently directing lights entered into the film to the front direction (projection direction).

[0010]

More specifically, it was found that superior front luminance could be achieved, if, when a cross section 100 was assumed along an arbitrary direction perpendicular to a film plane (plane of a surface on the side opposite to the side of the surface on which the rough surface is formed) as shown in Fig. 1, either one of a condition that average (θ_{ave}) of absolute values of slope (degree) of a curve defining the periphery of the cross section (profile curve 101) was within a predetermined range (condition A1) and a condition that ratio (L_r = L2/L1) of a length (L1) of a straight line 102 defined as an intersection of the film plane and the cross section and a length (L2) of the profile curve 101 was within a predetermined range (condition A2) was satisfied, and further, a condition that skewness P_{sk} (JIS B0601:2001) of the profile curve is within a predetermined range (conditions B1), or a condition that kurtosis P_{ku} (JIS B0601:2001) of the profile

curve is within a specific range (condition B2) was satisfied, and thus the present invention was accomplished.

[0011]

Among the aforementioned conditions, the values used for the conditions A1 and A2 are parameters determining degree of slopes of convexoconcaves existing on the film surface, and the values used for the conditions B1 and B2 are parameters determining shapes of convexoconcaves. Specifically, the skewness P_{sk} represents asymmetry, i.e., deviation degree, of heights of convexoconcaves (measure of asymmetry of probability density function for the height direction). For example, as for one convex shape, if it does not deviate from the central line, P_{sk} is 0, and a larger absolute value of P_{sk} represents larger deviation from the central line, while sign of P_{sk} differs depending on toward which direction the convex shape deviates. Further, the kurtosis P_{ku} represents sharpness of convexoconcaves (measure of sharpness of probability density function along the height direction), and when the probability density function has a shape of normal distribution, the kurtosis P_{ku} is 3. When the kurtosis P_{ku} has a value larger than that value, the convex portion should have a sharper shape, and when the kurtosis P_{ku} has a value smaller than that value, the convex portion should have a shape with a squashed apex. The light control film of the present invention satisfies, among such conditions concerning the slope and shape, at least one of A1 and A2, and at least one of B1 and B2.

[0012]

That is, the light control film of the present invention is a light control film having a rough surface, wherein the rough surface satisfies, for an arbitrary cross section perpendicular to a base plane of the film, a

condition that average (θ_{ave}, degree) of absolute values of slope with respect to the base plane of a curve along the edge of the cross section contoured by the rough surface (henceforth referred to as "profile curve") is not less than 20 degrees and not more than 75 degrees, and absolute value of skewness (JIS B0601:2001) of the profile curve is not more than 1.2 for substantially any profile curve (condition A1 + condition B1).

[0013]

The light control film of the present invention is also a light control film having a rough surface formed by a patterned layer comprising a material having a refractive index n, wherein the rough surface satisfies, for an arbitrary cross section perpendicular to a base plane of the film, a condition that average (θ_{ave}, degree) of absolute values of slope with respect to the base plane of a curve along the edge of the cross section contoured by the rough surface (henceforth referred to as "profile curve") is not less than (36 - 10n) degree and not more than (86 -10n), and absolute value of skewness (JIS B0601:2001) of the profile curve is not more than (n - 0.4) for substantially any profile curve (condition A1' (condition A1 considering the refractive index n) + condition B1).

[0014]

The light control film of the present invention is also a light control film having a rough surface, wherein the rough surface satisfies, for an arbitrary cross section perpendicular to a base plane of the film, a condition that average (θ_{ave}, degree) of absolute values of slope with respect to the base plane of a curve along the edge of the cross section contoured by the rough surface (henceforth referred to as "profile curve") is not less than 20 degrees

and not more than 75 degrees, and kurtosis (JIS B0601:2001) of the profile curve is not less than 1.5 and not more than 5.0 for substantially any profile curve (condition A1 + condition B2).

[0015]

The light control film of the present invention is also a light control film having a rough surface formed by a patterned layer comprising a material having a refractive index n, wherein the rough surface satisfies, for an arbitrary cross section perpendicular to a base plane of the film, a condition that average (θ_{ave}, degree) of absolute values of slope with respect to the base plane of a curve along the edge of the cross section contoured by the rough surface (henceforth referred to as "profile curve") is not less than (36 - 10n) degree and not more than (86 -10n), and kurtosis (JIS B0601:2001) of the profile curve is not less than 1.5 and not more than (10n - 11) for substantially any profile curve (condition A1' + condition B2).

[0016]

The light control film of the present invention is also a light control film having a rough surface, wherein the rough surface satisfies, for an arbitrary cross section perpendicular to a base plane of the film, a condition that ratio (L_r = L2/L1) of a length (L2) of a curve along the edge of the cross section contoured by the rough surface (henceforth referred to as "profile curve") to a length (L1) of a straight line defined as an intersection of the base plane and the cross section is $1.1 \leqq L_r \leqq 1.8$, and absolute value of skewness (JIS B0601:2001) of the profile curve is not more than 1.2 for substantially any cross section (condition A2 + condition B1).

[0017]

The light control film of the present invention is also a light control film having a rough surface formed by a patterned layer comprising a material having a refractive index n, wherein the rough surface satisfies, for an arbitrary cross section perpendicular to a base plane of the film, a condition that ratio (L_r = L2/L1) L_r) a length (L2) of a curve along the edge of the cross section contoured by the rough surface (henceforth referred to as "profile curve") to a length (L1) of a straight line defined as an intersection of the base plane and the cross section is $(1.9 - 0.5n) \leqq L_r \leqq 1.8$, and absolute value of skewness (JIS B0601:2001) of the profile curve is not more than (n - 0.4) for substantially any cross section (condition A2′ (condition A2 considering the refractive index n) + condition B1).

[0018]

Further, the light control film of the present invention is also a light control film having a rough surface, wherein the rough surface satisfies, for an arbitrary cross section perpendicular to a base plane of the film, a condition that ratio (L_r = L2/L1) of a length (L2) of a curve along the edge of the cross section contoured by the rough surface (henceforth referred to as "profile curve") to a length (L1) of a straight line defined as an intersection of the base plane and the cross section is $1.1 \leqq L_r \leqq 1.8$, and kurtosis (JIS B0601:2001) of the profile curve is not less than 1.0 and not more than 4.5 for substantially any cross section (condition A2 + condition B2).

[0019]

The light control film of the present invention is also a light control film having a rough surface formed by a patterned layer comprising a material having a refractive

index n, wherein the rough surface satisfies, for an arbitrary cross section perpendicular to a base plane of the film, a condition that ratio (L_r) of a length (L2) of a curve along the edge of the cross section contoured by the rough surface (henceforth referred to as "profile curve") to a length (L1) of a straight line defined as an intersection of the base plane and the cross section (L_r = L2/L1) is $(1.9 - 0.5n) \leqq L_r \leqq 1.8$, and kurtosis (JIS B0601:2001) of the profile curve is not less than 1.0 and not more than (10n - 11.5) for substantially any cross section (condition A2' + condition B2)

[0020]

In the present invention, the base plane of the film means a plane of the film regarded substantially planar, and when the face of the light control film of the present invention opposite to the face on which convexoconcaves are formed is smooth, the plane of this face can be regarded as the base plane. When the opposite face is not smooth but a rough surface, a plane including the central lines of two different directions thereof can be regarded as the base plane.

[0021]

When a profile curve is generally represented as y = f(x), the length (L2) of the profile curve with respect to such a base plane can be represented by the following equation (1) using f'(x) obtained by differentiating f(x) with x.

[0022]

[#1]

$$L2 = \int_0^{L1} \sqrt{1 + f'(x)^2 dx} \qquad (1)$$

[0023]

Further, slopes of the profile curve with respect to the base plane can be generally obtained as f'(x) obtained by differentiating f(x) with x, and average (S_{av}) of absolute values thereof can be represented by the following equation (2) wherein L represents the length of intervals for which the aforementioned values are calculated. Further, when the slopes are indicated in a unit of angle, the average of absolute values of such slopes (θ_{av}) can be represented by the following equation (3).

[0024]

[#2]

$$S_{av} = \frac{1}{L}\int_0^L |f'(x)|dx \qquad (2)$$

[0025]

[#3]

$$\theta_{av} = \frac{1}{L}\int_0^L \left|\tan^{-1} f'(x)\right|dx \qquad (3)$$

[0026]

However, although it is possible to use such a function for product designing, it is almost impossible to describe a profile curve with a general function for an actual product, and thus the length (L2) and the average of absolute values of slopes can hardly be obtained, either. Therefore, in the present invention, values calculated as follows are defined as the length of profile curve and average of absolute values of slope.

[0027]

First, a profile curve is measured from an arbitrary point of a rough surface along an arbitrary direction by using a surface profiler. The measurement results are constituted by height data measured at positions (d_1, d_2,

d_3 ... d_m) separated with a predetermined interval (Δd) each other, ($h(d_1)$, $h(d_2)$, $h(d_3)$ ... $h(d_m)$). These are data that can be represented as a curve in a graph in which the vertical axis indicates height of convexoconcaves and the horizontal axis indicates direction of profile curve, for example, as shown in Fig. 2. Portions of the profile curve each corresponding to one interval (e.g., (a-b), (c-d)) can be regarded as straight lines, if the interval is sufficiently short, and the lengths thereof λ_i ($i = 1, 2, 3 \ldots m-1$) can be represented by the following equation (4).

[0028]

[#4]

$$\lambda_i = \sqrt{(h(d_i) - h(d_{i+1}))^2 + \Delta d^2} \qquad (4)$$

[0029]

Then, the lengths obtained for all the portions of the profile curve corresponding to a predetermined interval (Δd) are summed to obtain L2.

[0030]

[#5]

$$L2 = \sum_{i=1}^{m-1} \lambda_i \qquad (5)$$

Further, absolute value θ_i ($i = 1, 2, 3 \ldots m-1$) of slope of a portion of the profile curve corresponding to one interval mentioned above can be represented by the following equation (6) (unit is "degree").

[0031]

[#6]

$$\theta_i = \tan^{-1}\left(\frac{h(d_{i+1}) - h(d_i)}{\Delta d}\right) \qquad (6)$$

[0032]

Further, average of the aforementioned slopes obtained for all the portions of the profile curve divided in the predetermined interval (Δd) as shown in the following equation (7) is used as the average of absolute values of slope θ_{ave}.

[0032]

[#7]

$$\theta_{ave} = \frac{1}{m}\sum_{i=1}^{m}|\theta_i| \qquad (7)$$

[0034]

The length of aforementioned interval (Δd) is such a length that the profile of the rough surface included in the profile curve can be sufficiently correctly reflected, and it is specifically an interval of about 1.0 μm or shorter.

[0035]

The backlight unit of the present invention is a backlight unit comprising a light guide plate provided with a light source for at least one end portion thereof and having a light emergent surface approximately perpendicular to the end portion and a light control film provided on the light emergent surface of the light guide plate, wherein the aforementioned light control film is used as the light control film.

The backlight unit of the present invention may be

the aforementioned backlight unit, wherein a prism sheet is used between the light control film and the light guide plate.

[0036]

The backlight unit of the present invention is also a backlight unit comprising a light source, a light diffusive plate provided on one side of the light source and a light control film provided on the side of the light diffusive plate opposite to the light source side, wherein the aforementioned light control film is used as the light control film.

[Effect of the Invention]

[0037]

The light control film of the present invention can increase components of lights of the front direction, in particular, those in the range of emission angle of 0 to 30 degrees, for lights entered from the surface opposite to the rough surface and emitted from the rough surface, and thus it can attain markedly higher front luminance compared with usual diffusing films. In addition, it also has appropriate light diffusing property and does not generate glare and interference pattern.

[0038]

Further, the backlight unit of the present invention is a backlight unit providing high front luminance, having appropriate light diffusing property, and not generating glare and interference pattern, because it uses the particular light control film. Moreover, it can prevent generation of scratches on a prism sheet due to contact with other members and so forth.

[Best Mode of Carrying Out the Invention]

[0039]

Hereafter, the light control film and backlight unit

of the present invention will be explained in detail with reference to the drawings. The sizes (thickness, width, height etc.) of the elements illustrated in the drawings used for explanation of the present invention are enlarged or reduced as required for explanation and do not reflect actual sizes of the elements of actual light control film and backlight unit.

[0040]

Figs. 3 (a) to (c) schematically show examples of the light control film of the present invention. As shown in the drawings, the light control film of the present invention has fine convexoconcaves formed on one face of a substantially planar film and has a characteristic profile of the convexoconcaves. The convexoconcaves may be formed on a layer provided on one face of a film used as a substrate as shown in (a) and (b), or the light control film may be constituted with a single layer on which convexoconcaves are formed as shown in (c).

[0041]

When lights enter into the light control film of the present invention from the surface opposite to the surface on which convexoconcaves are formed and are emitted from the rough surface, the light control film of the present invention controls direction of the lights so that components of lights emitted with an angle with respect to the front direction within a predetermined range should increase to enhance front luminance, and light diffusing property which can prevent glares should be provided. Although the surface opposite to the surface on which convexoconcaves are formed is typically a smooth surface, it is not limited to a smooth surface. For example, matting may be performed or a predetermined dot pattern etc. may be formed on the surface.

[0042]

Hereafter, the conditions concerning the profile of the convexoconcaves for controlling direction of lights described above will be explained.

[0043]

In the present invention, conditions for obtaining optimum emergent lights were first investigated for a single convex portion (Fig. 4-2) consisting of a revolution body formed by rotating such an arbitrary curve as shown in Fig. 4-1 on a xy-plane as a base plane around a z-axis perpendicular to the xy-plane by simulating relationship between incident lights and emergent lights in a three-dimensional space while changing the convex shape, height thereof, angle of incident light and so forth. And distribution of lights emerging from the convex side (emergent angle characteristics) was obtained by calculation for the case where lights having the same distribution as that of lights emerging from a light guide plate in an actual backlight unit enter from the bottom face side of the convex portion. The calculation was performed by assuming that the refractive index of the inside of the convex portion was 1.5, which is the refractive index of a common acrylic resin.

[0044]

Fig. 5 shows a graph representing distribution of emergent lights, which is a result of simulation performed for the convex portion having the shape shown in Fig. 4-2. In the graph, the solid line represents distribution of emergent lights, and the dotted line represents distribution of incident lights. In order to provide favorable front luminance and light scattering property of a certain degree, it is desirable that components of lights emergning with an angle within the range of the front

direction (0 degree) ± 30 degrees should be abundant.

[0045]

Then, in order to find conditions for obtaining emergent light characteristics satisfying such conditions for a rough surface on which multiple convex portions are formed, change of emergent light distribution was simulated while the shape of the convex portions and height thereof were variously changed for a system having a multiple number of the convex portions mentioned above.

The results of the simulation of the relationship between the average of absolute values of slope of profile curve (θ_{ave}) and energy of emergent lights are shown in the graph of Fig. 6. In the graph, the horizontal axis represents average of absolute values of slope of profile curve (θ_{ave}), and the vertical axis represents energy of emergent lights. The points of the first group 601 indicate energies of emergent lights within the range of not more than 6 degrees about the z axis (henceforth referred to as "emergent $lights_6$"), those of the second group 602 indicate energies of emergent lights within the range of not more than 18 degrees about the z axis (henceforth referred to as "emergent $lights_{18}$"), and those of the third group 603 indicate energies of emergent lights within the range of not more than 30 degrees about the z axis (henceforth referred to as "emergent $lights_{30}$").

[0046]

In the simulation results, there was observed a tendency that the ratio of the emergent $light_{30}$ increased as the average of absolute values of slopes (θ_{ave}) became larger, but when it became further larger exceeding a certain level, the ratio conversely decreased. Therefore, a comprehensive index of convexo-concave profile providing correlation with the emergent $light_{30}$ was investigated. As

a result, it was found that if the skewness P_{sk} defined in JIS B0601:2001 or the kurtosis P_{ku} defined in JIS B0601:2001 was used for a profile curve appearing on a rough surface of a light control film, the relation with the emergent $light_{30}$ could be best described.

[0047]

Figs. 7 and 8 show graphs representing the results of the simulation, and both represent change of the emergent light energy with change of the average of absolute values of slopes (θ_{ave}) plotted in the horizontal axis.

[0048]

From these simulation results, it was found that the energy of emergent lights having an emergent angle of 30 degrees or less tended to sharply increase when the average of absolute values of slope of the profile curve (θ_{ave}) was not less than 20 degrees and not more than 70 degrees, whereas there were some cases where the rate of the emergent $light_{30}$ did not become high even if the average of absolute values of slope of the profile curve (θ_{ave}) was within the aforementioned range. However, it was found that if only the results obtained with an absolute value of the skewness (P_{sk}) of the profile curve not more than 1.2 (points of "●" 604 in Fig. 7) were observed, the rate of the emergent $light_{30}$ was always high. Moreover, it was found that if only the results obtained with a kurtosis (P_{ku}) of the profile curve not less than 1.5 and not more than 5.0 (points of "●" 605 in Fig. 8) were observed, the rate of the emergent $light_{30}$ was always high.

[0049]

When the average of absolute values of slopes of the profile curve (θ_{ave}) is not less than 20 degrees and not more than 70 degrees, preferably not less than 20 degrees and not more than 60 degrees, more preferably not less than

20 degrees and not more than 50 degrees, if the absolute value of the skewness (P_{sk}) of the profile curve is not more than 1.2, preferably not more than 1.1, or the kurtosis (P_{ku}) of the profile curve is not less than 1.5 and not more than 5.0, preferably not less than 1.5 and not more than 4.5, particularly superior effect can be obtained.

[0050]

The results of the simulation of the relationship between the ratio (L_r) of the lengths of the profile curve and the energy of emergent lights are shown in Fig. 9. In the graph, the horizontal axis indicates ratio (L_r) of the length of the profile curve to a length of a straight line defined as an intersection of the base plane and the cross section, and the vertical axis indicates energy of emergent lights. The points of the first group 901 indicate energies of emergent lights within the range of not more than 6 degrees about the z axis (henceforth referred to as "emergent lights_6"), those of the second group 902 indicate energies of emergent lights within the range of not more than 18 degrees about the z axis (henceforth referred to as "emergent lights_{18}"), and those of the third group 903 indicate energies of emergent lights within the range of not more than 30 degrees about the z axis (henceforth referred to as "emergent lights_{30}").

[0051]

In the simulation results, there was observed a tendency that the ratio of the emergent light_{30} increased as the ratio (L_r) of the lengths became larger, but when it became further larger exceeding a certain level, the ratio conversely decreased. Therefore, a comprehensive index of convexo-concave profile providing correlation with the emergent light_{30} was investigated. As a result, it was found that if the skewness P_{sk} defined in JIS B0601:2001 or

the kurtosis P_{ku} defined in JIS B0601:2001 was used for a profile curve appearing on a rough surface of a light control film, the relation with the emergent light$_{30}$ can be best described.

[0052]

Figs. 10 and 11 show graphs representing the results of the simulation, and both represent change of the emergent light energy with change of the ratio of the lengths (L_r) plotted in the horizontal axis.

From these simulation results, it was found that the energy of emergent lights having an emergent angle of 30 degrees or less tended to sharply increase when the ratio of the lengths (L_r) was not less than 1.1 and not more than 1.8, whereas there were some cases where the rate of the emergent light$_{30}$ did not become high even if the ratio of the lengths (L_r) was within the aforementioned range. However, it was found that if only the results obtained with an absolute value of the skewness (P_{sk}) of the profile curve not more than 1.2 (points of "●" 904 in Fig. 10) were observed, the rate of the emergent light$_{30}$ was always high. Moreover, it was found that if only the results obtained with a kurtosis (P_{ku}) of the profile curve not less than 1.0 and not more than 4.5 (points of "●" 905 in Fig. 11) were observed, the rate of the emergent light$_{30}$ was always high.

[0053]

When the ratio of the lengths (L_r) is not less than 1.1 and not more than 1.8, preferably not less than 1.2 and not more than 1.7, more preferably not less than 1.3 and not more than 1.6, if the absolute value of the skewness (P_{sk}) of the profile curve is not more than 1.2, preferably not more than 1.1, or the kurtosis (P_{ku}) of the profile curve is not less than 1.0 and not more than 4.5,

preferably not less than 1.0 and not more than 4.0, particularly superior effect can be obtained.

[0054]

The conditions described above must be satisfied for substantially any cross section. The expression "substantially any section" is used to mean that it is sufficient that the conditions should be satisfied for almost all observed cross sections when observation is performed for multiple cross sections for a certain specific light control film, and it include a case that the conditions are not satisfied for one or two cross sections. For example, a cross section in an end portion of the light control film is considered as the cross section, the aforementioned conditions may not be satisfied, because convexoconcaves do not exist in a sufficient number. However, if the aforementioned conditions are satisfied for a comparatively long profile curve, it is considered that the aforementioned conditions are satisfied.

[0055]

In the aforementioned simulation for finding the conditions which the rough surface of the present invention must satisfy, the convex portions were assumed to consist of a material having a refractive index of 1.5. However, materials generally used for optical films can be used for the patterned layer of the light control film of the present invention, and the refractive index thereof is not limited to 1.5. If the condition is generalized in consideration of the refractive index n, when the average of absolute values of slope of the profile curve (θ_{ave}) is not less than (36 - 10n) degrees and not more than (86 - 10n) degrees, and the absolute value of skewness of the profile curve is not more than (n - 0.4) or the kurtosis of the profile curve is not less than 1.5 and not more than

(10n -11.5), the aforementioned effect can be obtained. Further, when the ratio of the lengths (L_r) is not less than (1.9 - 0.5n) and not more than 1.8, and the absolute value of skewness of the profile curve is not more than (n - 0.4) or the kurtosis of the profile curve is not less than 1.0 and not more than (10n - 11.5), the aforementioned effect can be obtained.

[0056]

By designing the convexo-concave profile in consideration of the refractive index of the material constituting the patterned layer as described above, the luminance for the front direction can be further improved.

[0057]

By designing the rough surface so that it should satisfy the aforementioned conditions, the light control film of the present invention can exhibit high front luminance, and have a light diffusing property of a certain degree. The light control film of the present invention having such characteristics is disposed, for example, directly on a light guide plate of a backlight unit of the edge light type, or via a light diffusive member on a light source of a backlight unit of the direct type, and used as a film for controlling the direction of emergent lights of the backlight unit.

[0058]

So long as the profile curves of the rough surface of the light control film of the present invention satisfy the aforementioned conditions, the shape and arrangement of the convex portions are not particularly limited. However, the convex portions and concave portions are preferably randomly arranged. If a random arrangement is used, it becomes easy to satisfy the aforementioned conditions for substantially any section, and generation of an

interference pattern can be easily prevented. Individual convex portions and concave portions may have the same shape or different shapes, and they may be arrange so that they should overlap with one another, or a part of all of the convex portions and concave portions should overlap with one another. The height of the convex portions and depth of the concave portions are both about 3 to 100 μm, and arrangement density of the convex portions or the concave portions is preferably about 10 to 200,000 portions/mm^2. A typical rough surface of the light control film satisfying the aforementioned conditions is shown in Fig. 12.

[0059]

Hereafter, specific configurations for producing the light control film having the aforementioned rough surface will be explained.

[0060]

As the material constituting the substrate 11 and the patterned layer 12 of the light control film 10 of the present invention, materials generally used for optical films can be used. Specifically, the material for the substrate 11 is not especially limited so long as a material exhibiting favorable light transmission property is chosen, and plastic films such as those of polyethylene terephthalate, polybutylene terephthalate, polyethylene naphthalate, polycarbonate, polyethylene, polypropylene, polystyrene, triacetyl cellulose, polyacrylate, polyvinyl chloride, and so forth can be used.

[0061]

The material for constituting the patterned layer 12 is not also especially limited so long as a material exhibiting favorable light transmission property is chosen, and glass, polymer resins, and so forth can be used.

Examples of the glass include oxide glass such as silicate glass, phosphate glass, and borate glass. Examples of the polymer resins include thermoplastic resins, thermosetting resins, and ionizing radiation curable resins such as polyester resins, acrylic resins, acrylic urethane resins, polyester acrylate resins, polyurethane acrylate resins, epoxy acrylate resins, urethane resins, epoxy resins, polycarbonate resins, cellulose resins, acetal resins, vinyl resins, polyethylene resins, polystyrene resins, polypropylene resins, polyamide resins, polyimide resins, melamine resins, phenol resins, silicone resins, and fluorocarbon resins, and so forth.

[0062]

Among these materials, polymer resins are preferred in view of workability and handling property, and those having a refractive index (JIS K7142:1996) of about 1.3 to 1.7 are especially preferably used. Even if a material having a refractive index n out of the aforementioned range is used as a material constituting the patterned layer, favorable luminance can be realized so long as the conditions (A1 OR A2) AND (B1 OR B2) are satisfied. However, by using a material having a refractive index within such a range, high luminance can be obtained. In particular, by designing the rough surface so that it should satisfy the conditions (A1′ OR A2′) AND (B1 OR B2) depending on the refractive index of the material, front luminance can be further improved.

[0063]

Although the patterned layer 12 may comprise light diffusing agents such as beads of organic materials and inorganic pigments, like general light diffusive sheets, they are not indispensable. The light control film of the present invention can exert light diffusing effect to a

certain degree by the rough surface itself, even if it does not comprise light diffusing agents. If light diffusing agents are not used, other members are not damaged by light diffusing agents, or light diffusing agents do not separate and fall to generate dusts.

[0064]

As the method for forming the patterned layer 12, 1) a method of using an embossing roller, 2) a method of using an etching treatment, and 3) a method of using molding with a mold can be employed. However, a production method of using a mold is preferred, because it enables production of light control films having a predetermined patterned layer with good reproducibility. Specifically, the production can be attained by preparing a mold having a profile complementary to that of the rough surface, casting a material constituting the patterned layer such as polymer resins into the mold, curing the material, and taking out the cured material from the mold. When a substrate is used, the production can be attained by casting a polymer resin or the like into the mold, superimposing a transparent substrate thereon, curing the polymer resin or the like, and taking out the cured material together with the transparent substrate from the mold.

[0065]

Although the method of forming a profile complementary to the rough surface in the mold is not particularly limited, the following method can be employed. For example, convex portions having a specific shape are formed on a plate so that the arrangement density of the portions should be several thousands portions/mm^2 by a laser microprocessing technique, and this plate is used as a male mold to prepare a mold for molding (female mold). The convex portions having a specific shape means such

convex portions that when profile curves are measured for one whole convex portion with equal intervals of a length that allows correct reflection of the shape of the convex portion (1.0 μm or shorter), the average thereof should satisfy the conditions (A1 or A2) and (B1 or B2). Alternatively, resin plates having a convex-concave layer are prepared by curing a resin containing particles of a predetermined particle size dispersed therein, the surfaces of the patterned layers are measured by using a surface profiler to choose a resin plate satisfying the aforementioned conditions, and a mold for molding (female mold) is prepared by using the chosen plate as a male mold.

[0066]

Although the surface of the light control film opposite to the surface consisting of the rough surface may be smooth, it may be subjected to a fine matting treatment in order to prevent generation of Newton rings when the film is brought into contact with a light guide plate or resin plate, or an antireflection treatment in order to improve light transmittance.

[0067]

Moreover, in order to obtain favorable front luminance, as an optical characteristic of the light control film, the film desirably has a haze of 60% or more, preferably 70% or more. The haze referred to herein is a value of the haze defined in JIS K7136:2000, and is a value obtained in accordance with the equation: Haze (%) = $[(\tau_4/\tau_2) - \tau_3(\tau_2/\tau_1)] \times 100$ (τ_1: flux of incident light, τ_2: total light flux transmitted through a test piece, τ_3: light flux diffused in a unit, τ_4: light flux diffused in the unit and test piece).

[0068]

Although the total thickness of the light control

film is not particularly limited, it is usually about 20 to 300 µm.

[0069]

The light control film of the present invention explained above is mainly used as a member of a backlight unit constituting a liquid crystal display, light signboard, and so forth.

[0070]

Hereafter, the backlight unit of the present invention will be explained. The backlight unit of the present invention consists of at least a light control film and a light source. As the light control film, the aforementioned light control film is used. Although the direction of the light control film arranged in the backlight unit is not particularly limited, it is preferably used so that the rough surface should serves as a light emergent surface side. For the backlight unit, a configuration called edge light type or direct type is preferably employed.

[0071]

A backlight unit of the edge light type consists of a light guide plate, a light source disposed on at least one end of the light guide plate, a light control film disposed on the light emergent surface side of the light guide plate, and so forth. The light control film is preferably used so that the rough surface should serve as the light emergent surface. Further, a prism sheet is preferably used between the light guide plate and the light control film. With such a configuration, a backlight unit exhibiting superior balance of front luminance and a view angle and not exhibiting glare, which is a problem peculiar to a prism sheet, can be provided.

[0072]

The light guide plate has a substantially plate-like shape at least one of which sides serves as a light entering surface and one of which surfaces perpendicular to the side serves as a light emergent surface, and mainly consists of a matrix resin selected from highly transparent resins such as polymethyl methacrylate. Resin particles having a refractive index different from that of the matrix resin may be added as required. Each surface of the light guide plate may not be a uniform plane, but has a complicated surface profile, or may be subjected to diffusion printing such as a dot pattern or the like.

[0073]

The light source is disposed for at least one end of the light guide plate, and a cold-cathode tube is mainly used. Examples of the shape of the light source include a linear shape, L-shape, and so forth.

[0074]

Besides the aforementioned light control film, light guide plate, and light source, the backlight unit of the edge light type is provided with a light reflector, a polarization film, an electromagnetic wave shield film etc. depending on the purpose.

[0075]

One embodiment of the backlight unit of the edge light type according to the present invention is shown in Fig. 13. This backlight unit 140 has a configuration that light sources 142 are provided on both sides of a light guide plate 141, and a light control film 143 is placed upside the light guide plate 141 so that a rough surface should be outside. The light sources 142 are covered with light source rear reflectors 144 except for the parts facing the light guide plate 141 so that lights from the light source should efficiently enter into the light guide

plate 141. Moreover, a light reflector 146 stored in a chassis 145 is provided under the light guide plate 141. By this configuration, lights emitted from the side of the light guide plate 141 opposite to the emergent side are returned into the light guide plate 141 again to increase lights emerging from the emergent surface of the light guide plate 141.

[0076]

A backlight unit of the direct type consists of a light control film, and a light diffusive member and a light source disposed in this order on a surface of the light control film opposite to the light emergent surface, and so forth. The light control film is preferably used so that the rough surface should serve as the light emergent surface. Moreover, a prism sheet is preferably used between the light diffusive member and the light control film. With such a configuration, a backlight unit exhibiting superior balance of front luminance and a view angle and not exhibiting glare, which is a problem peculiar to a prism sheet, can be provided.

[0077]

The light diffusive member is for erasing a pattern of the light source, and a milky resin plate, a transparent substrate on which a dot pattern is formed on a portion corresponding to the light source (lighting curtain) as well as a so-called light diffusing film having a convexo-concave light diffusing layer on a transparent substrate, and so forth can be used individually or in a suitable combination.

[0078]

As the light source, a cold-cathode tube is mainly used. Examples of the shape of the light source include a linear shape, L-shape, and so forth. Besides the

aforementioned light control film, light diffusive member, and light source, the backlight unit of the direct type may be provided with a light reflector, a polarization film, an electromagnetic wave shield film, etc. depending on the purpose.

[0079]

One embodiment of the backlight unit of the direct type according to the present invention is shown in Fig. 14. This backlight unit 150 has a configuration that plural light sources 152 are provided above a light reflector 156 stored in a chassis 155, and a light control film 153 is placed thereon via a light diffusive member 157 as shown in the drawing.

[0080]

Because the backlight unit of the present invention utilizes a light control film having a specific rough surface as a light control film that controls direction of lights emitted from a light source or a light guide plate, it can improve front luminance compared with conventional backlights, and suffers from the problem of glare and generation of scratches in less degrees compared with the case of using a prism sheet alone.

[Examples]

[0081]

Hereafter, the present invention will be further explained with reference to examples.

[Examples 1 to 4]

Four kinds of molds (1) to (4) on which predetermined convexo-concave profiles were formed by a laser microprocessing technique were prepared, an ultraviolet curable resin having a refractive index of 1.50 was poured into the molds (1) to (3), and a silicone resin having a refractive index of 1.40 was poured into the mold (4).

Subsequently, the poured resins were cured, and then taken out from the molds to obtain light control films (1) to (4) having a size of 23 cm (for the direction perpendicular to the light source) x 31 cm (for the direction parallel to the light source) (light control films of Examples 1 to 4).

[0082]

Then, surface profiles of the rough surfaces (light emergent surface) of the light control films (1) to (4) were measured according to JIS B0601:2001 by using a surface profiler (SAS-2010 SAU-II, MEISHIN KOKI). This surface profiler had a contact finger in the shape of a cone with a spherical tip of which radius was 2 μm and conical angle of 60 degrees. The measurement interval was 1.0 μm. The measurement was performed at arbitrary 5 positions on each light control film for arbitrary directions, and averages of absolute values of slopes to the light entering surface (θ_{ave}) of the obtained profile curves were calculated. Further, for the same profile curves, values of the skewness (P_{sk}) defined in JIS B0601:2001 were obtained. The results obtained for the light control films (1) to (4) are shown in Table 1 (unit of slope is "degree"). Further, by using a turbidimeter (NDH2000, Nippon Denshoku), hazes of the light control films (1) to (4) were measured according to JIS K7136:2000. The measurement results are also shown in Table 1.

[0083]

[Table 1]

	θ_{ave} (degree)	$\vert P_{sk}\vert$	haze (%)
Example1	43.6	0.916	97.3
	44.1	0.937	
	42.4	0.940	
	44.7	0.958	
	45.4	0.926	
Example2	38.6	0.595	75.5
	37.5	0.599	
	37.9	0.596	
	38.5	0.613	
	40.4	0.609	
Example3	25.5	0.055	78.9
	25.6	0.057	
	26.4	0.057	
	24.5	0.057	
	26.6	0.053	
Example4	38.6	0.645	74.6
	37.7	0.663	
	39.8	0.655	
	37.0	0.622	
	36.8	0.630	

[0084]

As seen from the results shown in Table 1, the light control films of Examples 1 to 4 showed averages of absolute values of slopes not less than 20 degrees and not more than 75 degrees for all the profile curves. Further,

the absolute values of the skewness were not more than 1.2 for all the profile curves. Moreover, all the light control films of Examples 1 to 4 had a haze of 70% or higher, and thus satisfied the optical characteristics required for obtaining favorable front luminance.

[0085]

Then, the light control films (1) to (4) were each incorporated into a 15-inch edge light type backlight unit (one cold-cathode tube was provided for each of upside and downside), and front luminance was measured. That is, the light control films (1) to (4) were each disposed on a light guide plate so that the rough surface should serve as the light emergent surface, and the luminance was measured at each emergent angle for the parallel and perpendicular directions with respect to the light source (cold-cathode tubes) positioned at the center of the backlight unit (1 inch = 2.54 cm). The results obtained for the light control films (1) to (4) are shown in Table 2 (unit is "cd/m^2").

[0086]

[Table 2]

		luminance (cd/m^2)			
		Example 1	Example 2	Example 3	Example 4
parallel direction	left 45 deg.	1010	1030	1100	1050
	left 30 deg.	2160	2100	1860	2020
	0 deg.	2460	2380	2030	2260
	right 30 deg.	2120	2070	1840	1990
	right 45 deg.	999	1020	1090	1040
perpendicular direction	up 45 deg.	713	772	1030	860
	up 30 deg.	2290	2240	2010	2160
	0 deg.	2460	2380	2030	2260
	down 30 deg.	2270	2220	2010	2150
	down 45 deg.	703	762	1020	850

[0087]

It was demonstrated by the results shown in Table 2 that, for the light control films of Examples 1 to 4, only by incorporating one sheet of light control film into the backlight unit, the luminance for emergent angles of 30 degrees or less could be increased, and thus strong emergent lights could be obtained for the front direction.

[0088]

[Examples 5 to 8]

Four kinds of molds (5) to (8) on which predetermined convexo-concave profiles were formed by a laser microprocessing technique were prepared, an ultraviolet curable resin having a refractive index of 1.50 was poured into the molds (5) to (7), and a silicone resin having a refractive index of 1.40 was poured into the mold (8).

Subsequently, the poured resins were cured, and then taken out from the molds to obtain light control films (5) to (8) having a size of 23 cm x 31 cm (light control films of Examples 5 to 8).

[0089]

Then, surface profiles of the rough surfaces (light emergent surfaces) of the light control films (5) to (8) were measured according to JIS B0601:2001 in the same manner as that used in Examples 1 to 4. The measurement was performed at arbitrary 5 positions on each light control film for arbitrary directions, and averages of absolute values of slopes to the light entering surface of the obtained profile curves (θ_{ave}) were calculated. Further, for the same profile curves, values of the kurtosis (P_{ku}) defined in JIS B0601:2001 were obtained. The results obtained for the light control films (5) to (8) are shown in Table 3 (unit of slope is "degree"). Further, by using a turbidimeter (NDH2000, Nippon Denshoku), hazes of the light control films (5) to (8) were measured according to JIS K7136:2000. The measurement results are also shown in Table 3.

[0090]

[Table 3]

	θ_{ave} (degree)	P_{ku}	haze (%)
Example 5	42.3	2.590	82.7
	40.8	2.472	
	40.9	2.515	
	43.8	2.580	
	41.6	2.618	
Example 6	38.0	2.260	82.1
	36.9	2.268	
	36.8	2.347	
	38.5	2.320	
	37.1	2.267	
Example 7	24.5	1.925	77.5
	23.9	1.930	
	24.1	1.971	
	24.7	1.962	
	24.7	1.837	
Example 8	25.3	3.885	82.0
	25.9	4.058	
	24.6	3.835	
	25.5	3.697	
	24.6	3.932	

[0091]

As seen from the results shown in Table 3, the light

control films of the examples showed averages of absolute values of slopes not less than 20 degrees and not more than 75 degrees for all the profile curves. Further, the absolute values of the kurtosis were not less than 1.5 and not more than 5.0 for all the profile curves. Moreover, all the light control films of Examples 5 to 8 had a haze of 70% or higher, and thus satisfied the optical characteristics required for obtaining favorable front luminance.

[0092]

Then, the light control films (5) to (8) were each incorporated into a 15-inch edge light type backlight unit (one cold-cathode tube was provided for each of upside and downside), and front luminance was measured. That is, the light control films (5) to (8) were each disposed on a light guide plate so that the rough surface should serve as the light emergent surface, and the luminance was measured at each emergent angler for the parallel and perpendicular directions with respect to the light source (cold-cathode tubes) positioned at the center of the backlight unit (1 inch = 2.54 cm). The results obtained for the light control films (5) to (8) are shown in Table 4 (unit is "cd/m^2").

[0093]

[Table 4]

		luminance (cd/m²)			
		Example5	Example6	Example7	Example8
parallel direction	left 45deg.	1020	1050	1100	1060
	left 30deg.	2110	2010	1840	1970
	0deg.	2390	2240	2000	2190
	right 30deg.	2070	1980	1820	1940
	right 45deg.	1010	1040	1090	1050
perpendicular direction	up 45deg.	764	875	1050	911
	up 30deg.	2240	2150	1990	2120
	0deg.	2390	2240	2000	2190
	down 30deg.	2230	2140	1980	2110
	down 45deg.	754	865	1040	901

[0094]

It was demonstrated by the results shown in Table 4 that, for the light control films of Examples 5 to 8, only by incorporating one sheet of light control film into the backlight unit, the luminance for emergent anglers of 30 degrees or less could be increased, and thus strong emergent lights could be obtained for the front direction.

[0095]

[Comparative Examples 1 to 3]

Three kinds of molds (9) to (11) on which predetermined convexo-concave profiles were formed by a laser microprocessing technique were prepared, and an ultraviolet curable resin having a refractive index of 1.50 was poured into the molds. Subsequently, the poured resin was cured, and then taken out from the molds to

obtain light control films (9) to (11) having a size of 23 cm x 31 cm (light control films of Comparative Examples 1 to 3).

[0096]

Then, surface profiles of the rough surfaces (light emergent surfaces) of the light control films (9) to (11) were measured according to JIS B0601:2001 in the same manner as that used in Examples 1 to 4. For the obtained profile curves, averages of absolute values of slopes to the light entering surface (θ_{ave}) were calculated. Further, for the same profile curves, values of the skewness (P_{sk}) defined in JIS B0601:2001 were obtained. The results obtained for the light control films (9) to (11) are shown in Table 5 (unit of slope is "degree").

[0097]

[Table 5]

	θ_{ave} (degree)	$\mid P_{sk} \mid$	haze (%)
Comparative Example 1	31.9	1.261	80.6
	32.8	1.251	
	32.5	1.310	
	31.8	1.303	
	33.0	1.229	
Comparative Example 2	25.1	1.755	72.7
	25.6	1.673	
	24.6	1.719	
	25.5	1.759	
	25.4	1.786	
Comparative Example 3	20.3	2.159	68.0
	20.8	2.221	
	20.4	2.123	
	20.3	2.185	
	21.2	2.130	

[0098]

As seen from the results shown in Table 5, the light control films of Comparative Examples 1 to 3 showed averages of absolute values of slopes not less than 20 degrees and not more than 75 degrees for all the profile curves. However, the absolute values of the skewness was

more than 1.2 for all the profile curves.

[0099]

Then, the light control films (9) to (11) were each incorporated into a 15-inch edge light type backlight unit (one cold-cathode tube was provided for each of upside and downside), and front luminance was measured. That is, the light control films (9) to (11) were each disposed on a light guide plate so that the rough surface of the light control film should serve as the light emergent surface, and the luminance was measured at each emergent angler for the parallel and perpendicular directions with respect to the light source (cold-cathode tubes) positioned at the center of the backlight unit (1 inch = 2.54 cm). The results obtained for the light control films (9) to (11) are shown in Table 6.

[0100]

[Table 6]

		luminance (cd/m^2)		
		Comparative Example 1	Comparative Example 2	Comparative Example 3
parallel direction	left 45deg.	1220	1230	1240
	left 30deg.	1470	1430	1380
	0deg.	1440	1390	1320
	right 30deg.	1460	1430	1380
	right 45deg.	1210	1220	1230
perpendicular direction	up 45deg.	1460	1500	1550
	up 30deg.	1630	1600	1550
	0deg.	1440	1390	1320
	down 30deg.	1640	1610	1570
	down 45deg.	1450	1490	1540

[0101]

It was found from the results shown in Table 6 that when the light control films of Comparative Examples 1 to 3 were incorporated into the backlight unit, front luminance was not sufficient.

[0102]

[Comparative Examples 4 to 6]

Three kinds of molds (12) to (14) on which predetermined convexo-concave profiles were formed by a laser microprocessing technique were prepared, and an ultraviolet curable resin having a refractive index of 1.50 was poured into the molds. Subsequently, the poured

resin was cured, and then taken out from the molds to obtain light control films (12) to (14) having a size of 23 cm x 31 cm (light control films of Comparative Examples 4 to 6).

[0103]

Then, surface profiles of the rough surfaces (light emergent surfaces) of the light control films (12) to (14) were measured according to JIS B0601:2001 in the same manner as that used in the examples. For the obtained profile curves, averages of absolute values of slopes to the light entering surface (θ_{ave}) were calculated. Further, for the same profile curves, values of the kurtosis (P_{ku}) defined in JIS B0601:2001 were obtained. The results obtained for the light control films (12) to (14) are shown in Table 7 (unit of slope is "degree").

[0104]

[Table 7]

	θ_{avc} (degree)	P_{ku}	haze (%)
Comparative Example 4	21.2	7.720	73.2
	21.3	7.918	
	21.0	8.042	
	20.3	7.349	
	20.6	7.600	
Comparative Example 5	25.1	1.351	75.8
	25.7	1.347	
	24.4	1.306	
	25.7	1.416	
	24.8	1.299	
Comparative Example 6	31.2	5.885	77.1
	32.3	5.809	
	30.0	6.002	
	30.3	5.759	
	30.8	5.672	

[0105]

As seen from the results shown in Table 7, the light control films of Comparative Examples 4 to 6 showed averages of absolute values of slopes not less than 20 degrees and not more than 75 degrees for all the profile curves. However, the absolute values of the kurtosis were less than 1.5 or more than 5.0 for all the profile curves.

[0106]

Then, the light control films (12) to (14) were each incorporated into a 15-inch edge light type backlight unit (one cold-cathode tube was provided for each of upside and downside), and front luminance was measured. That is, the light control films (12) to (14) were each disposed on a light guide plate so that the rough surface of the light control film should serve as the light emergent surface, and the luminance was measured at each emergent angler for the parallel and perpendicular directions with respect to the light source (cold-cathode tubes) positioned at the center of the backlight unit (1 inch = 2.54 cm). The results obtained for the light control films (12) to (14) are shown in Table 8 (unit is "cd/m^2").

[0107]

[Table 8]

		luminance (cd/m^2)		
		Comparative Example 4	Comparative Example 5	Comparative Example 6
parallel direction	left 45deg.	1240	1190	1230
	left 30deg.	1390	1540	1430
	0deg.	1330	1550	1390
	right 30deg.	1390	1530	1430
	right 45deg.	1230	1190	1220
perpendicular direction	up 45deg.	1540	1380	1490
	up 30deg.	1560	1700	1610
	0deg.	1330	1550	1390
	down 30deg.	1580	1710	1620
	down 45deg.	1530	1370	1480

[0108]

It can be seen from the results shown in Table 8 that when the light control films of Comparative Examples 4 to 6 were incorporated into the backlight unit, front luminance was not sufficient.

[0109]

[Comparative Examples 7 and 8]

For commercially available light diffusive sheets (Comparative Examples 7 and 8), surface profiles of rough surfaces (light emergent surfaces) were measured at arbitrary 5 positions on each sheet in the same manner as that used in the examples, and averages of absolute values

of slopes of the profile curves (θ_{ave}) were obtained. Further, for the same profile curves, the skewness (P_{sk}) and the kurtosis (P_{ku}) were calculated. The results are shown in Table 9.

[0110]

[Table 9]

	θ_{ave} (degree)	$\lvert P_{sk} \rvert$	P_{ku}
Comparative Example 7	17.1	0.131	3.329
	17.2	0.130	3.277
	16.8	0.133	3.482
	16.9	0.126	3.261
	17.2	0.135	3.422
Comparative Example 8	10.9	0.752	3.673
	10.7	0.750	3.813
	10.5	0.736	3.618
	10.9	0.747	3.736
	11.1	0.736	3.691

[0111]

As seen from the results shown in Table 9, the light diffusive sheets of Comparative Examples 7 and 8 were those that could not provide an average of absolute values of slopes not less than 20 degrees and not more than 75 degrees at all the measurement points.

[0112]

Then, the light diffusive sheets of Comparative Examples 7 and 8 were each incorporated into a 15-inch edge light type backlight unit (one cold-cathode tube was provided for each of upside and downside), and front luminance was measured. That is, the light diffusive sheets of Comparative Examples 7 and 8 were each disposed on a light guide plate so that the rough surface of the light diffusive sheet should serve as the light emergent surface, and the luminance was measured at each emergent angler for the parallel and perpendicular directions with respect to the light source (cold-cathode tubes) positioned at the center of the backlight unit (1 inch = 2.54 cm). The results are shown in Table 10.

[0113]

[Table 10]

		luminance (cd/m^2)	
		Comparative Example 7	Comparative Example 8
parallel direction	left 45 deg	1190	1260
	left 30 deg.	1560	1330
	0 deg.	1580	1240
	right 30 deg.	1550	1330
	right 45 deg.	1180	1250
perpendicular direction	up 45 deg.	1360	1610
	up 30 deg.	1720	1500
	0 deg.	1580	1240
	down 30 deg.	1730	1520
	down 45 deg.	1350	1600

[0114]

As seen from the results shown in Table 10, when the conventional light diffusive sheets were incorporated into the backlight unit, favorable front luminance could not be obtained.

[0115]

[Examples 9 to 12]

Four kinds of molds (15) to (18) on which predetermined convexo-concave profiles were formed by a laser microprocessing technique were prepared, an

ultraviolet curable resin having a refractive index of 1.50 was poured into the molds (15) to (17), and a silicone resin having a refractive index of 1.40 was poured into the mold (18). Subsequently, the poured resins were cured, and then taken out from the molds to obtain light control films (15) to (18) having a size of 23 cm (for the direction perpendicular to the light source) x 31 cm (for the direction parallel to the light source) (light control films of Examples 9 to 12).

[0116]

Then, surface profiles of the rough surfaces (light emergent surface) of the light control films (15) to (18) were measured according to JIS B0601:2001 by using a surface profiler (SAS-2010 SAU-II, MEISHIN KOKI). This surface profiler had a contact finger in the shape of a cone with a spherical tip of which radius was 2 μm and conical angle of 60 degrees. The measurement interval was 1.0 μm.

[0117]

The measurement was performed at arbitrary 5 positions on each light control film for arbitrary directions, lengths of the obtained profile curves (L2) were measured, and ratios (L_r) thereof to the lengths of bases of the sections (L1) (L_r = L2/L1) were calculated. Further, for the same profile curves, values of the skewness (P_{sk}) defined in JIS B0601:2001 were obtained. The results obtained for the light control films (15) to (18) are shown in Table 11 (unit of slope is "degree"). Further, by using a turbidimeter (NDH2000, Nippon Denshoku), hazes of the light control films (15) to (18) were measured according to JIS K7136:2000. The measurement results are also shown in Table 11.

[0118]

[Table 11]

	L_x	$\|P_{sk}\|$	haze (%)
Example 9	1.677	0.097	82.7
	1.630	0.097	
	1.654	0.095	
	1.650	0.101	
	1.661	0.094	
Example 10	1.392	0.248	82.1
	1.330	0.237	
	1.360	0.253	
	1.341	0.251	
	1.346	0.237	
Example 11	1.265	0.461	96.5
	1.215	0.483	
	1.202	0.439	
	1.262	0.455	
	1.254	0.459	
Example 12	1.455	0.120	82.5
	1.489	0.126	
	1.450	0.117	
	1.513	0.126	
	1.457	0.121	

[0119]

As seen from the results shown in Table 11, the light control films of Examples 9 to 12 showed ratios of the

lengths (L_r) not less than 1.1 and not more than 1.8 for all the profile curves. Further, the absolute values of the skewness were not more than 1.2 for all the profile curves. Moreover, all the light control films of Examples 9 to 12 had a haze of 70% or higher, and thus satisfied the optical characteristics required for obtaining favorable front luminance.

[0120]

Then, the light control films (15) to (18) were each incorporated into a 15-inch edge light type backlight unit (one cold-cathode tube was provided for each of upside and downside), and front luminance was measured. That is, the light control films (15) to (18) were each disposed on a light guide plate so that the rough surface should serve as the light emergent surface, and the luminance was measured at each emergent angler for the parallel and perpendicular directions with respect to the light source (cold-cathode tubes) positioned at the center of the backlight unit (1 inch = 2.54 cm). The results obtained for the light control films (15) to (18) are shown in Table 12 (unit is "cd/m^2").

[0121]

[Table 12]

		luminance (cd/m²)			
		Example 9	Example 10	Example 11	Example 12
parallel direction	L45deg.	1090	1090	1110	1110
	L30deg.	1820	1800	1750	1770
	0deg.	1920	1900	1830	1850
	R30deg.	1800	1790	1740	1750
	R45deg.	1100	1100	1120	1100
perpendicular direction	U45deg.	1060	1070	1130	1110
	U30deg.	1950	1930	1880	1900
	0deg.	1920	1900	1830	1850
	D30deg.	1950	1930	1900	1900
	D45deg.	1090	1110	1160	1140

[0122]

It was demonstrated by the results shown in Table 12 that, for the light control films of Examples 9 to 12, only by incorporating one sheet of light control film into the backlight unit, the luminance for emergent anglers of 30 degrees or less could be increased, and thus strong emergent lights could be obtained for the front direction.

[0123]

[Examples 13 to 16]

Four kinds of molds (19) to (22) on which predetermined convexo-concave profiles were formed by a laser microprocessing technique were prepared, an ultraviolet curable resin having a refractive index of 1.50 was poured into the molds (19) to (21), and a silicone

resin having a refractive index of 1.40 was poured into the mold (22). Subsequently, the poured resins were cured, and then taken out from the molds to obtain light control films (19) to (22) having a size of 23 cm x 31 cm (light control films of Examples 13 to 16).

[0124]

Then, surface profiles of the rough surfaces (light emergent surface) of the light control films (19) to (22) were measured according to JIS B0601:2001 in the same manner as that used in Examples 1 to 4. The measurement was performed at arbitrary 5 positions on each light control film for arbitrary directions, lengths of the obtained profile curves (L2) were measured, and ratios (L_r) thereof to the lengths of bases of the sections (L1) (L_r = L2/L1) were calculated. Further, for the same profile curves, values of the kurtosis (P_{ku}) defined in JIS B0601:2001 were obtained. The results obtained for the light control films (19) to (22) are shown in Table 13 (unit of slope is "degree"). Further, by using a turbidimeter (NDH2000, Nippon Denshoku), hazes of the light control films (19) to (22) were measured according to JIS K7136:2000. The measurement results are also shown in Table 13.

[0125]

[Table 13]

	L_r	P_{ku}	haze (%)
Example 13	1.685	1.651	82.3
	1.679	1.651	
	1.761	1.700	
	1.657	1.624	
	1.682	1.676	
Example 14	1.376	4.023	76.2
	1.326	4.032	
	1.333	3.848	
	1.316	4.141	
	1.418	3.942	
Example 15	1.288	2.146	82.6
	1.250	2.206	
	1.261	2.148	
	1.275	2.248	
	1.276	2.099	
Example 16	1.326	2.260	94.3
	1.391	2.343	
	1.381	2.197	
	1.365	2.244	
	1.323	2.372	

[0126]

As seen from the results shown in Table 13, the light control films of the examples showed ratios of the lengths

(L_r) not less than 1.1 and not more than 1.8 for all the profile curves. Further, the absolute values of the kurtosis were not less than 1.0 and not more than 4.5 for all the profile curves. Moreover, all the light control films of Examples 13 to 16 had a haze of 70% or higher, and thus satisfied the optical characteristics required for obtaining favorable front luminance.

[0127]

Then, the light control films (19) to (22) were each incorporated into a 15-inch edge light type backlight unit (one cold-cathode tube was provided for each of upside and downside), and front luminance was measured. That is, the light control films (19) to (22) were each disposed on a light guide plate so that the rough surface should serve as the light emergent surface, and the luminance was measured at each emergent angler for the parallel and perpendicular directions with respect to the light source (cold-cathode tubes) positioned at the center of the backlight unit (1 inch = 2.54 cm). The results obtained for the light control films (19) to (22) are shown in Table 14 (unit is "cd/m^2").

[0128]

[Table 14]

		luminance (cd/m²)			
		Example13	Example14	Example15	Example16
parallel direction	Left 45 deg.	1140	1130	1130	1070
	Left 30 deg.	1660	1690	1690	1880
	0 deg.	1700	1740	2010	1870
	Right 30 deg.	1630	1680	1670	1860
	Right 45 deg.	1150	1140	1140	1080
perpendicular direction	Up 45 deg.	1240	1200	1200	984
	Up 30 deg.	1800	1830	1830	2010
	0 deg.	1700	1740	2010	1870
	Down 30 deg.	1810	1840	1830	2000
	Down 45 deg.	1260	1230	1220	1020

[0129]

It was demonstrated by the results shown in Table 14 that, for the light control films of Examples 13 to 16, only by incorporating one sheet of light control film into the backlight unit, the luminance for emergent anglers of 30 degrees or less could be increased, and thus strong emergent lights could be obtained for the front direction.

[0130]

[Comparative Examples 9 to 11]

Three kinds of molds (23) to (25) on which predetermined convexo-concave profiles were formed by a laser microprocessing technique were prepared, and an ultraviolet curable resin having a refractive index of 1.50 was poured into the molds. Subsequently, the poured resin was cured, and then taken out from the molds to obtain light control films (23) to (25) having a size of 23 cm x

31 cm (light control films of Comparative Examples 9 to 11).

[0131]

Then, surface profiles of the rough surfaces (light emergent surfaces) of the light control films (23) to (25) were measured according to JIS B0601:2001 in the same manner as that used in Examples 1 to 4. The lengths of the obtained profile curves (L2) were measured, and ratios (L_r) thereof to the lengths of bases of the sections (L1) (L_r = L2/L1) were calculated. Further, for the same profile curves, values of the skewness (P_{sk}) defined in JIS B0601:2001 were obtained. The results obtained for the light control films (23) to (25) are shown in Table 15 (unit of slope is "degree").

[0132]

[Table 15]

	L_r	$\|P_{sk}\|$	haze (%)
Comparative Example 9	1.202	1.261	81.5
	1.143	1.236	
	1.161	1.302	
	1.162	1.261	
	1.234	1.304	
Comparative Example 10	1.141	1.755	60.8
	1.186	1.741	
	1.113	1.785	
	1.166	1.708	
	1.130	1.719	
Comparative Example 11	1.121	2.159	64.4
	1.153	2.246	
	1.168	2.655	
	1.143	2.243	
	1.170	2.225	

[0133]

As seen from the results shown in Table 15, the light control films of Comparative Examples 9 to 11 showed ratios of the lengths (L_r) not less than 1.1 and not more than 1.8 for all the profile curves. However, the absolute values of the skewness were more than 1.2 for all the profile curves.

[0134]

Then, the light control films (23) to (25) were each incorporated into a 15-inch edge light type backlight unit (one cold-cathode tube was provided for each of upside and downside), and front luminance was measured. That is, the light control films (23) to (25) were each disposed on a light guide plate so that the rough surface of the light control film should serve as the light emergent surface, and the luminance was measured at each emergent angler for the parallel and perpendicular directions with respect to the light source (cold-cathode tubes) positioned at the center of the backlight unit (1 inch = 2.54 cm). The results obtained for the light control films (23) to (25) are shown in Table 16.

[0135]

[Table 16]

		luminance (cd/m^2)		
		Comparative Example 9	Comparative Example 10	Comparative Example 11
parallel direction	left 45 deg.	1210	1250	1260
	left 30 deg.	1480	1380	1340
	0 deg.	1450	1300	1240
	right 30 deg.	1470	1370	1330
	right 45 deg.	1200	1240	1210
perpendicular direction	up 45 deg.	1440	1560	1600
	up 30 deg.	1640	1530	1510
	0 deg.	1450	1300	1240
	down 30 deg.	1650	1560	1500
	down 45 deg.	1440	1550	1590

[0136]

It was found from the results shown in Table 16 that when the light control films of Comparative Examples 9 to 11 were incorporated into the backlight unit, front luminance was not sufficient.

[0137]

[Comparative Examples 12 to 14]

Three kinds of molds (26) to (28) on which predetermined convexo-concave profiles were formed by a laser microprocessing technique were prepared, and an ultraviolet curable resin having a refractive index of 1.50 was poured into the molds. Subsequently, the poured resin was cured, and then taken out from the molds to obtain light control films (26) to (28) having a size of 23

cm x 31 cm (light control films of Comparative Examples 12 to 14).

[0138]

Then, surface profiles of the rough surfaces (light emergent surfaces) of the light control films (26) to (28) were measured according to JIS B0601:2001 in the same manner as that used in the examples. The lengths of the obtained profile curves (L2) were measured, and ratios (L_r) thereof to the lengths of bases of the sections (L1) (L_r = L2/L1) were calculated. Further, for the same profile curves, values of the kurtosis (P_{ku}) defined in JIS B0601:2001 were obtained. The results obtained for the light control films (26) to (28) are shown in Table 17 (unit of slope is "degree").

[0139]

[Table 17]

	L_r	P_{ku}	haze (%)
Comparative Example 12	1. 162	4. 573	74. 4
	1. 171	4. 772	
	1. 133	4. 654	
	1. 214	4. 666	
	1. 106	4. 721	
Comparative Example 13	1. 424	4. 885	65. 6
	1. 407	4. 925	
	1. 389	4. 782	
	1. 376	4. 807	
	1. 394	5. 059	
Comparative Example 14	1. 221	7. 720	64. 3
	1. 163	7. 856	
	1. 201	8. 028	
	1. 238	8. 596	
	1. 267	8. 973	

[0140]

As seen from the results shown in Table 17, the light control films of Comparative Examples 12 to 14 showed ratios of the lengths (L_r) not less than 1.1 and not more than 1.8 for all the profile curves. However, the absolute values of the kurtosis were less than 1.0 or more than 4.5 for all the profile curves.

[0141]

Then, the light control films (26) to (28) were each incorporated into a 15-inch edge light type backlight unit (one cold-cathode tube was provided for each of upside and downside), and front luminance was measured. That is, the light control films (26) to (28) were each disposed on a light guide plate so that the rough surface of the light control film should serve as the light emergent surface, and the luminance was measured at each emergent angler for the parallel and perpendicular directions with respect to the light source (cold-cathode tubes) positioned at the center of the backlight unit (1 inch = 2.54 cm). The results obtained for the light control films (26) to (28) are shown in Table 18 (unit is "cd/m^2").

[0142]

[Table 18]

		luminance (cd/m²)		
		Comparative Example 12	Comparative Example 13	Comparative Example 14
parallel direction	left 45 deg.	1210	1220	1240
	left 30 deg.	1470	1440	1380
	0 deg.	1440	1390	1320
	right 30 deg.	1470	1430	1390
	right 45 deg.	1210	1220	1230
perpendicular direction	up 45 deg.	1450	1450	1550
	up 30 deg.	1630	1600	1550
	0 deg.	1440	1390	1320
	down 30 deg.	1640	1610	1570
	down 45 deg.	1450	1490	1540

[0143]

It was found from the results shown in Table 18 that when the light control films of Comparative Examples 12 to 14 were incorporated into the backlight unit, front luminance was not sufficient.

[0144]

[Comparative Examples 15 and 16]

For commercially available light diffusive sheets (Comparative Examples 15 and 16), surface profiles of rough surfaces (light emergent surfaces) were measured at arbitrary 5 positions on each sheet in the same manner as that used in the examples, lengths of the measured profile curves (L2) were measured, and ratios (L_r) thereof to the

lengths of bases of the sections (L1) (L_r = L2/L1) were calculated. Further, for the same profile curves, the skewness (P_{sk}) and the kurtosis (P_{ku}) were calculated. The results obtained for the light diffusive sheets of Comparative Examples 15 and 16 are shown in Table 19.

[0145]

[Table 19]

	L_r	$\lvert P_{sk} \rvert$	P_{ku}
Comparative Example 15	1.078	0.177	3.436
	1.071	0.169	3.303
	1.069	0.176	3.389
	1.064	0.168	3.274
	1.066	0.174	3.498
Comparative Example 16	1.035	0.725	3.673
	1.064	0.722	3.702
	1.065	0.747	3.557
	1.029	0.701	3.622
	1.028	0.689	3.574

[0146]

As seen from the results shown in Table 19, the light diffusive sheets of Comparative Examples 15 and 16 were those that could not provide a ratio of the lengths (L_r) not less than 1.1 and not more than 1.8 at all the measurement points.

[0147]

Then, the light diffusive sheets of Comparative Examples 15 and 16 were each incorporated into a 15-inch edge light type backlight unit (one cold-cathode tube was

provided for each of upside and downside), and front luminance was measured. That is, the light diffusive sheets of Comparative Examples 15 and 16 were each disposed on a light guide plate so that the rough surface of the light diffusive sheet should serve as the light emergent surface, and the luminance was measured at each emergent angler for the parallel and perpendicular directions with respect to the light source (cold-cathode tubes) positioned at the center of the backlight unit (1 inch = 2.54 cm). The results are shown in Table 20.

[0148]

[Table 20]

		luminance (cd/m^2)	
		Comparative Example 7	Comparative Example 8
parallel direction	left 45 deg.	1180	1260
	left 30 deg.	1560	1330
	0 deg.	1560	1240
	right 30 deg.	1550	1330
	right 45 deg.	1180	1250
perpendicular direction	up 45 deg.	1350	1610
	up 30 deg.	1710	1500
	0 deg.	1560	1240
	down 30 deg.	1720	1520
	down 45 deg.	1360	1600

[0149]

As seen from the results shown in Table 20, when the conventional light diffusive sheets were incorporated into the backlight unit, favorable front luminance could not be obtained.

[0150]

As clearly seen from the results of the aforementioned examples, the light control films of the examples exhibited superior front luminance and appropriate light diffusing property, because the rough surfaces thereof were designed so that they should satisfy the

specific configuration. Further, by incorporating such light control films into a backlight unit, backlight units exhibiting high front luminance and not suffering from glare and generation of a interference pattern could be obtained.

Brief Description of the Drawings

[0151]

[Fig. 1] Drawing for explanation of the rough surface of the light control film of the present invention

[Fig. 2] Drawing for explanation of the profile curve of the light control film of the present invention

[Fig. 3] Sectional views showing embodiments of the light control film of the present invention

[Fig. 4-1] Sectional view of a three-dimensional shape of a convex portion used for simulating difference in emergent angler characteristics caused by the shape

[Fig. 4-2] Drawing showing an example of three-dimensional shape of convex portion used for simulating difference in emergent angler characteristics caused by the shape

[Fig. 5] Drawing showing results of three-dimensional simulation

[Fig. 6] Drawing showing results of three-dimensional simulation

[Fig. 7] Drawing showing results of three-dimensional simulation

[Fig. 8] Drawing showing results of three-dimensional simulation

[Fig. 9] Drawing showing results of three-dimensional simulation

[Fig. 10] Drawing showing results of three-dimensional simulation

[Fig. 11] Drawing showing results of three-dimensional simulation

[Fig. 12] Perspective view of an example of the rough surface of the light control film of present invention
[Fig. 13] Drawing showing an embodiment of the backlight unit of the present invention
[Fig. 14] Drawing showing an embodiment of the backlight unit of the present invention